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Dated 4 August 2003

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P01/7700 0.00-0216487.9

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office
Cardiff Road
Newport
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NP10 8QQ

1. Your reference

566GB

2. Patent a
(The Pate)

0216487.9

16 JUL 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Renishaw plc
New Mills
Wotton-under-Edge
Gloucestershire, GL12 8JR

Patents ADP number *(if you know it)*

2691002

If the applicant is a corporate body, give the country/state of its incorporation

United Kingdom

4. Title of the invention

A Rotary Scale

5. Name of your agent *(if you have one)*

E C Leland et al

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Renishaw plc, Patent Department
New Mills
Wotton-under-Edge
Gloucestershire
GL12 8JR

Patents ADP number *(if you know it)*

8187421001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
–	–	–

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*
–	–

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

Yes

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Continuation sheets of this form	0
Description	8
Claim(s)	0
Abstract	0
Drawing(s)	4 only (1)

10. If you are also filing any of the following, state how many against each item.

Priority documents	0
Translations of priority documents	0
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	0
Request for preliminary examination and search *(Patents Form 9/77)*	0
Request for substantive examination *(Patents Form 10/77)*	0
Any other documents *(please specify)*	0

11. I/We request the grant of a patent on the basis of this application.

Signature E. Iles Date 16.07.02

AGENT FOR THE APPLICANT

12. Name and daytime telephone number of person to contact in the United Kingdom

A ILES 01453 524524

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.

b) Write your answers in capital letters using black ink or you may type them.

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d) If you have answered 'Yes' Patents Form 7/77 will need to be filed.

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A ROTARY SCALE

The present invention relates to a rotary scale for use in opto-electronic scale reading apparatus.

A known form of opto-electronic scale reading apparatus for measuring relative displacement of two members comprises a scale on one of the members, having scale marks defining a pattern and a readhead on the other of the members. The readhead includes a light source for illuminating the scale, periodic diffraction means for interacting with light reflected from the scale marks to produce interference fringes at the readhead. Relative movement of the scale and readhead cause the interference fringes to move relative to the readhead. Detecting means are responsive to the movement of the fringes and produce a measure of displacement.

An example of such apparatus is disclosed in EP-A-0 207 121 and also US-A-4 974 962, each of which shows the means for illuminating the scale and the periodic diffraction means in the read head. US-A-4 926 566 discloses a method of producing a scale, in the form of a flexible tape produced by rolling. This method may produce a scale in which the pitch of the scale marks is, for example, 20μm or 40μm.

For measuring rotary displacement, a scale is held around a cylindrical surface which rotates in use with a shaft or other rotary part relative to a readhead. This apparatus is typically called a rotary encoder.

Our European Patent application 1094302 discloses a rotary encoder in which a ring is used to hold a length

of scale in the form of metallic tape on an outer surface. The ring is fitted onto a rotary part of a machine. The inner circumferential surface of the ring and the rotary part of the machine onto which the ring is fitted are both tapered. This removes the need for close tolerances on the diameters of the ring and the rotary part. In addition it enables the adjustment of the centre of the ring.

According to a first aspect of the invention there is provided a rotary ring for use in scale reading apparatus, comprising:

a flexible ring, the flexible ring having scale markings provided on a surface thereof.

A second aspect of the present invention provides a method of mounted a flexible rotary scale onto a rotary part of a machine comprising:

stretching or shrinking the flexible rotary scale over a feature of the rotary part.

The manufacturing tolerance of the rotary scale or differential e.g. thermal expansion is thus taken up by stretching or shrinking it into place.

The feature may comprise an annular protrusion. The protrusion may be integral with the rotary ring or may be separate.

Alternatively, the feature may comprise a tapered surface. The flexible rotary scale may also have a tapered surface. Preferably the tapered surfaces form a self-locking taper.

The present invention will now be described, by way of example, with reference to the accompanying drawing, in which:

Fig 1 is a perspective view of the ring of the present invention;

Fig 2 is a plan view of a length of flexible scale use to make the ring of the present invention;

Fig 3 is a cross-section of a length of tapered flexible scale;

Fig 4 is a cross-section of a ring mounted over an annular protrusion on a rotary part of a machine;

Figs 5 and 6 are cross-sections of a ring being mounted over a tapered protrusion on a rotary part of a machine;

Fig 7 is a cross-section of a ring mounted over an O-ring mounted on a rotary part of a machine;

Fig 8 is a cross-section of a ring mounted on a tapered rotary part of a machine;

Fig 9 is a cross-section of a tapered ring mounted on a tapered rotary part of a machine;

Fig 10 is a plan view of a garter spring mounted between a flexible ring and machine shaft;

Fig 11 is a plan view of a corrugated spring mounted between a flexible ring and a machine shaft; and

Fig 12 is a perspective view of part of the corrugated spring illustrated in Fig 11.

Fig 1 illustrates a rotary ring of the present invention. A flexible ring 10 is provided with scale marks 14 defining a pattern along one surface. The scale marks may for example define a periodic pattern to form an incremental scale or define a pseudorandom sequence or discrete codewords to form an absolute

position scale. The scale marks may be provided directly on a surface of the rotary ring or may be provided on a tape which is secured to a surface of the rotary ring. The ring 10 may be made from a length of linear scale formed from a length of flexible tape 12 as shown in Fig 2. Such a linear scale is disclosed in our earlier patent US 4926566 and may be made by subjecting a length of tape to an embossing process to form a profile comprising a sequence of troughs and crests. The embossing process may entail, for example, passing the scale between rollers, one of which has a profiled surface corresponding to the desired profile of the scale.

The rotary ring 10 is formed by bending the linear scale 12 into a ring and joining the two opposite ends 16,18 together by any suitable method, for example by welding. In particular, the ends of the tape may be buck welded or laser welded together.

Alternatively the scale marks may be put onto a flexible ring by any suitable technique, for example etching. The flexible ring may be formed by deposition or machining from a solid, for example.

Fig 1 shows the ring 10 having the scale markings 14 on the outer circumferential surface. Alternatively the scale markings may be provided on the inner circumferential surface. In this case mounting the ring onto a machine part is inverted such that the outer circumferential surface of the ring is mounted on the machine part.

The ring 10 shown in Fig 1 may be provided with a

tapered surface 20, as shown by the cross-section of the ring in Fig 3.

This flexible ring has the advantage that it is smaller and lighter than solid rings.

A further advantage is that the flexible ring can fit within the desired application with the minimum of space or constraint on design. Use of the flexible ring has almost the same effect as putting the graduations directly on the prime components but with the advantage that the flexible ring may be replaced if damaged.

The ring is mounted on a rotary part of a machine and a readhead is mounted on a stationary part of the machine. Alternatively, the ring may be mounted on a stationary part of the machine and the readhead may be mounted on a rotary part of the machine. In previous types of rotary rings, mounting screws may be provided to fix the ring to the rotary part. This is not possible with the thin flexible ring and thus other means of fixing the ring onto the rotary part must be used. When the ring is mounted on the rotary part of the machine, it is desirable that the manufacturing tolerance of the ring is taken up.

Methods of mounting the flexible ring onto a rotary part of a machine will now be described with reference to Figs 4-9.

Figs 4-7 all illustrate the ring 10 fitted onto a rotary part 22 of a machine in which the rotary part has been provided with features to secure the ring in

place.

Fig 4 illustrates a rotary part 22 with an annular protrusion 26. The ring 10 is pushed onto this protrusion 26 such that the protrusion is located at the centre of the scale, causing the scale to deflect around the protrusion, fixing it in place. Although the scale is deflected when in position, the readhead 24 is positioned to read the centre of the scale which is negligibly distorted.

Figs 5 and 6 illustrates a different feature on the rotary part of the machine. In this embodiment the rotary part 22 is provided with a tapered surface 28 at the upper section of the rotary part 22 and a recessed portion 30 at the lower section of the rotary part. As shown in Fig 5, the ring 10 is pushed onto the tapered surface 28, which stretches the ring, taking up the manufacturing tolerance. Once the bottom portion of the ring reaches the recess 30, the ring will be held in position, as shown in Fig 6, deflected over the tapered surface 28, with one side deflected on the tapered surface 28, the other side deflected into the recess 30 and the central portion at the widest part of the taper. At the widest part of the scale, the taper may flatten out, to provide a flatter area for the centre of the ring to minimise distortions of the scale as read by the readhead.

The features of the rotary part are not necessarily integral with the rotary part. Fig 7 illustrates an embodiment in which the feature is provided by an O-ring 32 fitted around the rotary part 22. The circumferential surface of the rotary part may be provided with a annular recess 34 in which to locate

the O-ring 32. The ring 10 is pushed over the O-ring 32 in the same manner as in the other embodiments.

The "o"-ring may include any ring-shaped flexible arrangement, for example a garter spring 40 as illustrated in Fig 10 or a spring 42 having a corrugated cross-section as illustrated in Fig 11 and shown in more detail in Fig 12.

Figs 8 and 9 illustrate a rotary part 22 of a machine provided with a tapered surface 36. In Fig 8 the ring 10 also has a tapered surface 38, the tapered surface corresponding to that on the tapered rotary part. The tapered ring is pushed down over the tapered rotary part and as the diameter of the rotary part increases down the taper, the manufacturing tolerance of the ring is taken up. The taper angles of the tapered rotary part and ring are chosen such that the taper is a self-locking taper. In a locking taper, the angle of friction is less than the coefficient of friction and the frictional forces between the parts (i.e. the ring and rotary part) are so great that they will not rotate or move with respect to one another. Thus no other clamping forces are required to keep the parts joined together and a considerable force is required to separate the two parts.

In Fig 9 a non-tapered ring 10 is pushed over the tapered rotary part 22. As the ring 10 is pushed over the tapered surface 36 of the rotary part 22, the ring 22 is stretched. As with the tapered ring, this ring is held in place by friction.

The ring of the present invention may also be fitted

onto the rotary part by shrink fitting or use of adhesive.

Shrink fitting is suitable, for example, for any of the mounting techniques described with reference to Figs 4-9 or onto a machine shaft with parallel sides.

The above methods have the advantage that the ring may be quickly and easily fitted into place on the rotary ring without the need for mounting fixtures, such as screws. The process of stretching or shrinking the flexible scale into places ensures that the manufacturing tolerances of the scale are taken up.

If required, the ring may be adjusted axially to provide a fine radial run out correction, for example as disclosed in European Patent Application No. EP1094302.

This invention is not limited to use with optical scales. It is also suitable, for example, for use with magnetic scales.

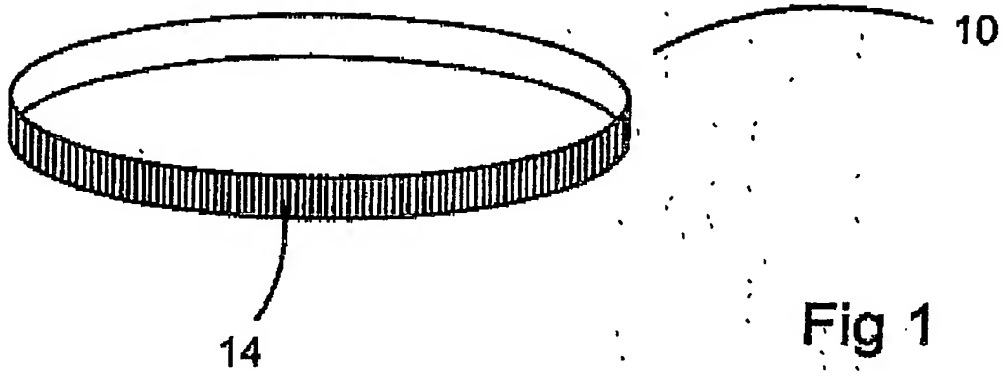

Fig 1

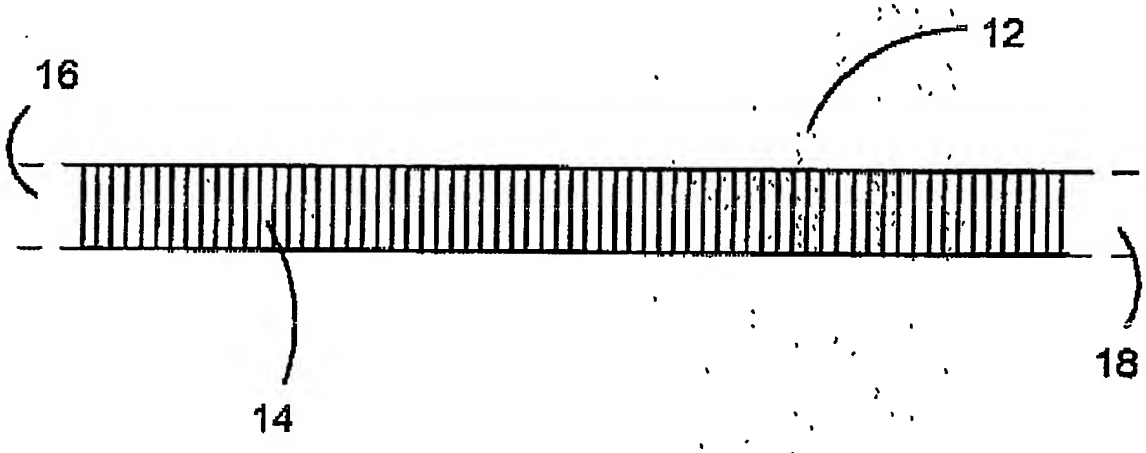

Fig 2

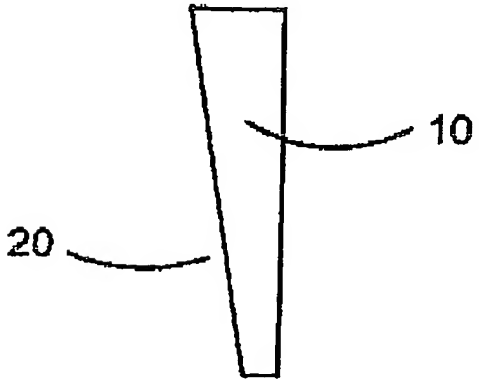

Fig 3

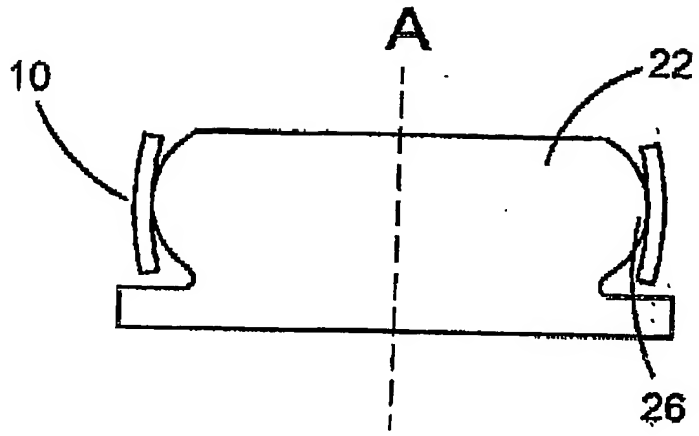

Fig 4

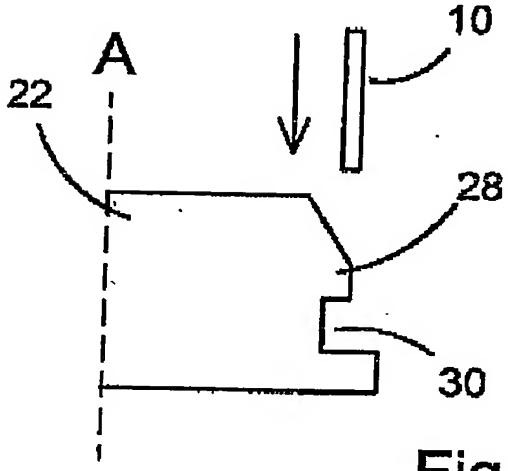

Fig 5

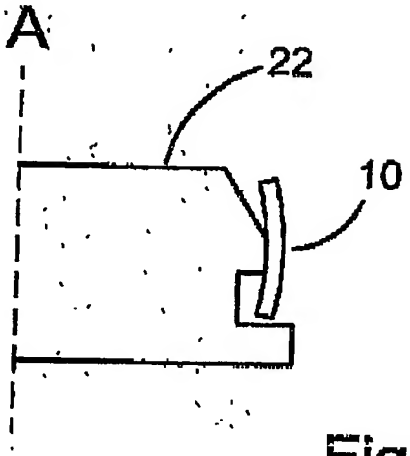

Fig 6

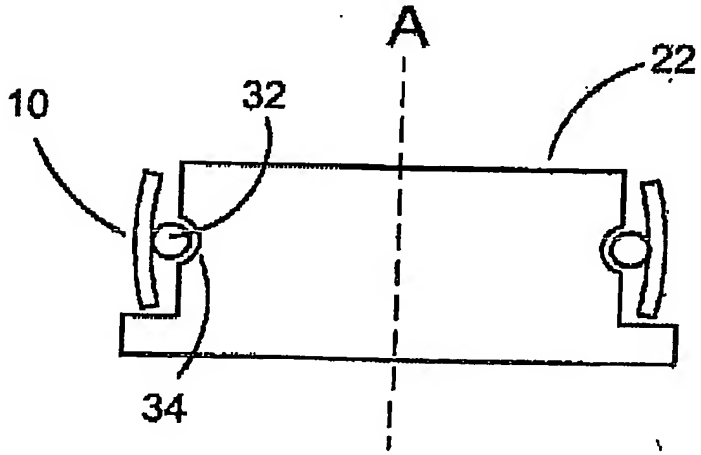

Fig 7

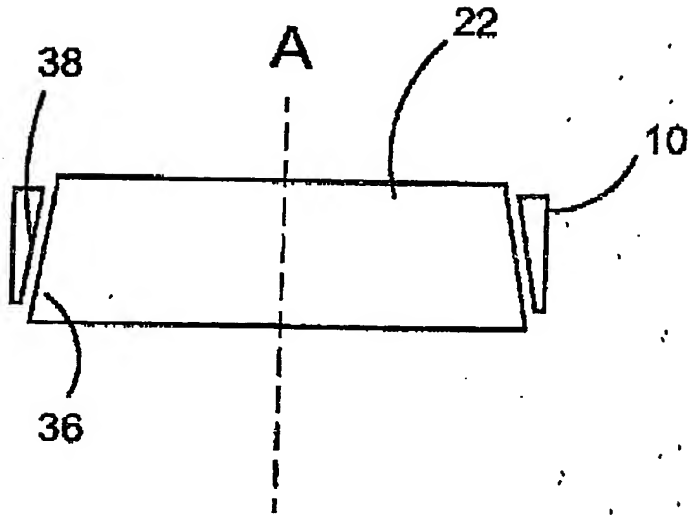

Fig 8

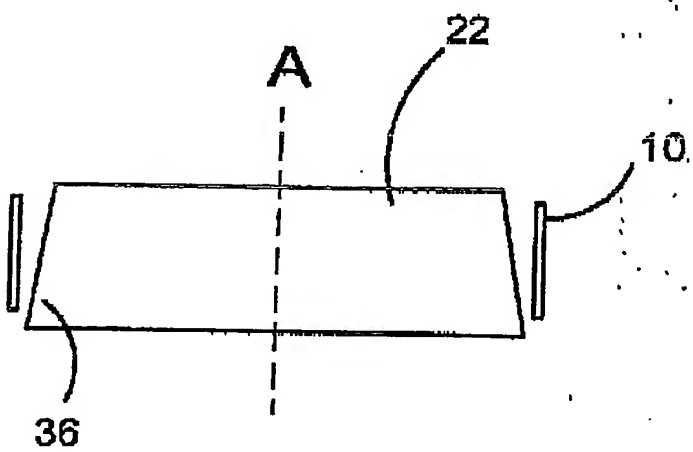

Fig 9

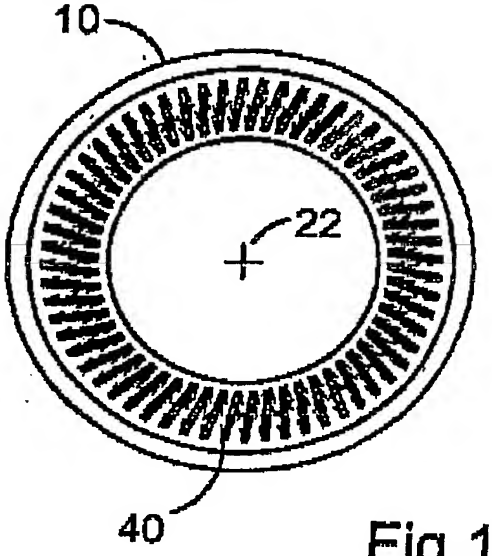

Fig 10

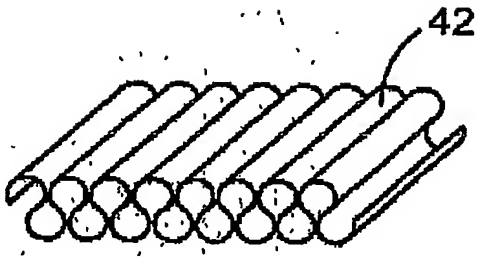

Fig 12

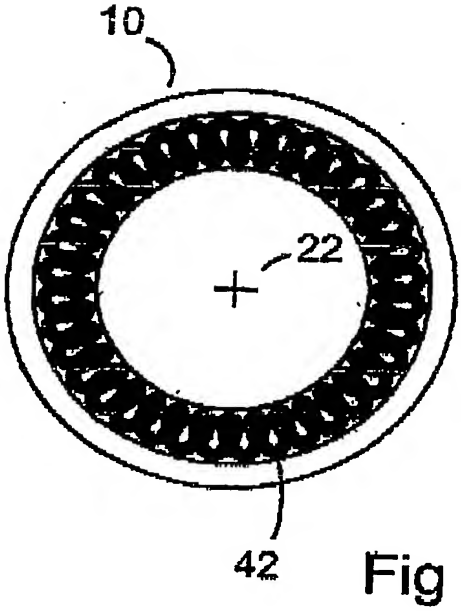

Fig 11